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The Air Quality and Noise Impact of a Warm Fog Dispersal System Using Momentum Driven Heat Sources

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The impact of a Warm Fog Dispersal System (WFDS) on the air quality and noise level is assessed. The WFDS, designed by AFGL, uses various combinations of heat and thrust to disperse the fog over the runway and approach zones. Emission and noise levels that are within the state-of-the-art are used in this assessment. Calculations show that within the cleared area the pollution concentrations, on the average, are within the EPA standards.

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Because of the large number of combustors in a WFDS, the noise level drops off slowly with distance. This could pose a problem to nearby noise sensitive areas such as residential areas, schools, and hospitals.

Preface

The author wishes to thank Dr. Alan I. Weinstein of AFGL for his review and constructive criticisms of the final manuscript.

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The Air Quality and Noise Impact of a Warm Fog Dispersal System Using Momentum Driven Heat Sources

1. INTRODUCTION

Warm fog is responsible for the overwhelming majority of all the visibility restrictions and associated delays that occur at airports throughout the world. To date, the only proven technique for dispersing warm fog at airports on an operational basis is the application of heat from an array of ground based sources. This technique requires the consumption of large amounts of fuel which undoubtedly will have an impact on the air quality. In the past, designs of such a system did not have to address the problem of environmental impact as long as the particulate matter that was emitted did not degrade the visibility significantly. In today's world, any new development requires a close evaluation of its impact on the environment. A modern Warm Fog Dispersal System (WFDS) of the type considered here may use a combination of heat and thrust. The thrust is used to project the heat over the desired clear zone. This type of thermokinetic system may generate substantial noise which, if not adequately planned for, may create a nuisance to the surrounding community. The purpose of this study is to assess the impact of a modern WFDS using momentum driven heat sources on the air quality and noise level.

As a result of field tests of a sub-scale fog dispersal system, Kunkel[1] determined the heat and thrust requirements and combustor layout for a full scale WFDS. These

(Received for publication 1 September 1976)

1. Kunkel, B. A. (1975) Heat and Thrust Requirements of a Thermal Fog Dispersal System, AFCRL-TR-75-0472.

specifications are used in this study to assess the impact of a modern WFDS. Until the combustors are developed and emission levels are measured, certain assumptions on the emission outputs will have to be made. This report may, therefore, be viewed as a preliminary assessment, but one that is based on emission levels that can be reasonably obtained with today's technology.

2. DESIGN OF A WARM FOG DISPERSAL SYSTEM (WFDS) USING MOMENTUM DRIVEN HEAT SOURCES

2.1 Clearing Geometry

The heat and thrust requirements of a WFDS depend on the dimensions of the volume to be cleared. The volume that must be cleared and the level of improvement necessary to permit landing operations depend upon the level of sophistication of the electronic landing aids present at the airport. A Category I landing system requires a minimum visibility of 800 m and a decision height of 60 m. The more sophisticated Category II landing system requires a minimum visibility of 400 m and a decision height of 30 m. The Air Force requires Category I landing conditions. Therefore, this report will discuss the environmental impact of a Category I WFDS. Since more combustors and fuel will be required to produce adequate clearings for a Category I landing system than for a Category II system, the impact on the environment will be greatest for a Category I WFDS.

Figure 1 shows the volume in which the visibility must be raised to at least 800 m for a Category I landing system. The intended clearing can be divided into two zones — the approach zone (A) and the rollout zone (R). The Air Force system being designed to satisfy Multi-Command ROC 508-74, Warm Fog Dispersal System (WFDS), will produce a clearing in the approach zone that starts at a point 300 m upstream of the intersection of the glide slope and the decision height (DH). These 300 m represent approximately 5 sec of flight time for most aircraft on their final approach. This 5-sec period will give the incoming pilot time to make his decision to continue on if he can see the ground, or execute a missed approach if he cannot. The clearing height in the approach zone is tapered from a maximum height of 80 m to a height of 15 m at a point 450 m down runway of the touchdown point (GPI) or 750 m from the runway threshold. The clearing height over the remainder of the runway is 50 m. The clearing width in the approach zone is approximately 150 m near the decision point, narrowing down to approximately the width of the runway at the touchdown point. Along the runway, the clearing width is approximately the width of the runway.

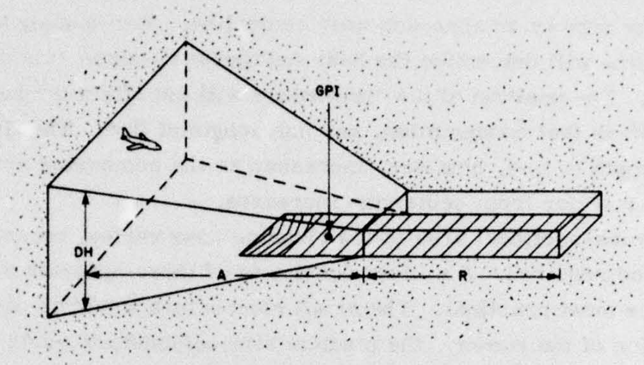

Figure 1. Clearing Geometry of WFDS

2.2 System Layout and Design

The WFDS design, based on the work of Kunkel,[1] consists of lines of combustors on each side of the runway and approach, as shown in Figure 2. The combustors extend along the full length of the runway or to a suitable exit ramp and 1400 m into the approach zone from the runway threshold.

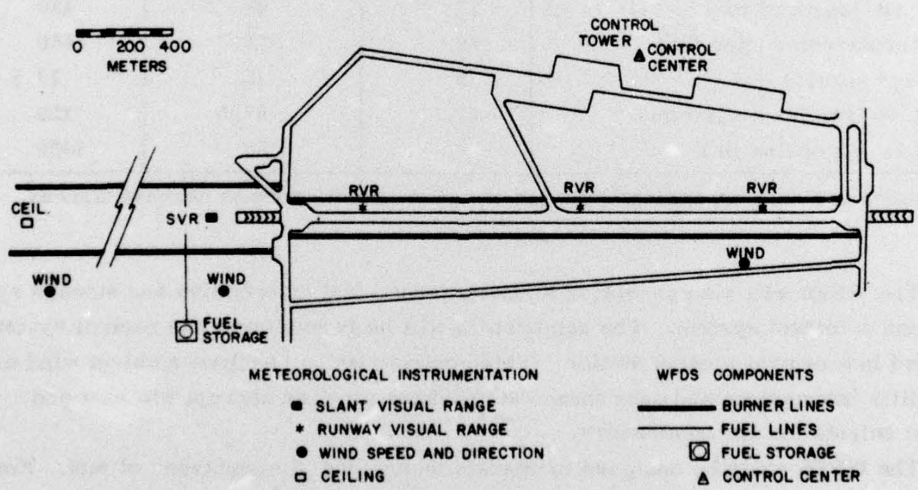

Figure 2. Schematic Layout of WFDS Using Momentum Driven Heat Sources

The position of the combustors is flexible within certain limits. Spacing between combustors can vary up to a maximum limit. That limit is a function of the distance from the runway or approach zone centerline. The spacing and distance from the centerline will determine the heat and thrust requirements of the individual combustors. The position of the combustors will not affect the heat requirement, and therefore fuel consumption, per unit length of line. The thrust requirement per unit length of line, however, increases as the combustor spacing decreases and the position from centerline increases.

Since the cross-sectional area of the clearing zone varies, more than one size combustor will be required. A system consisting of three different size combustors appears to be the most practical. The small combustors would be installed along the rollout portion of the runway, the medium size combustors would be near the touchdown area, and the large combustors would be in the approach zone. Table 1 shows the heat and thrust requirements of such a system along with the spacing and distance from the centerline. The spacing of the combustors in the approach and touchdown zones may decrease as the cross-sectional area increases to allow more heat and thrust per unit length.

Table 1. Heat and Thrust Requirements and Combustor Configuration for a WFDS Using Momentum Driven Heat Sources

	Rollout	Touchdown	Approach
Avg heat/length of rwy (kcal/m/sec)	31	46	139
Max thrust/combustor (kg)	59	77	450
Average spacing (m)	15	15	22.5
Distance from centerline(m)	67.5	67.5	120
Total length of line (m)	*	750	1400

*Distance variable depending on length of runway or distance to nearest taxiway.

The WFDS will also consist of an underground fuel distribution and storage system and a control system. The combustors will be regulated by the control system located in a central control station. This control station receives ambient wind and visibility information and uses these data to determine the appropriate heat and thrust outputs for the combustors.

The WFDS could be designed to operate on any one of many types of fuel. For this study it will be assumed the system operates on JP-4 fuel since this is the fuel that is most readily available at most airfields. Propane and natural gas are also possible candidates. However, since they are cleaner burning fuels than JP-4, their use will have less of an impact on the air quality.

3. ENVIRONMENTAL IMPACT

3.1 Emission Criteria

Most emission regulations are designed for a particular type of facility such as power plants, foundries, incinerators, cement plants, smelters, pulp mills, etc. Even within a given type of facility there may be different emission limits depending on the size of the facility and/or the type of fuel burned.

Since no WFDS of this type exists in the United States, it is not surprising that emission standards have not yet been promulgated for such a facility. The emission limits should depend on the impact of the facility on the air quality. The impact that the system has on the air quality will depend on the background air quality, the size and frequency of use of the system, and the distance to residential areas, hospitals, etc. Facilities near large metropolitan areas may require very stringent emission limitations because of the already high concentration of pollutants and the heavily populated area surrounding the airport. Facilities at remote airports might have less stringent limitations because of the relatively low background pollution levels and the sparsely populated area surrounding the airport.

There are five pollutants of primary concern. These are carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x), sulfur dioxide (SO_2) and particulates. There are no known national emission standards for CO and HC. The emission levels for these two pollutants can be specified in terms of combustor inefficiency (CI), (Private communication, Air Force Aero Propulsion Laboratory) as given by Eq. (1).

$$CI = \frac{EI_{co}\, QL_{co} + EI_{hc}\, QL_{hc}}{1000\, QL_{fuel}} , \tag{1}$$

where QL is the constant pressure lower heating value for the exhaust constituents in cal/g of pollutants, and EI is the emission index in g of pollutant/kg of fuel. The values of QL for the various constituents are:

$$QL_{HC} = 9000 - 11,000 \text{ cal/g HC},$$

$$QL_{CO} = 2410 \text{ cal/g CO},$$

$$QL_{fuel} = 10,380 \text{ cal/g fuel (JP-4)}.$$

These values can be obtained from any number of chemical or mechanical engineering handbooks. For most combustors using JP-4 fuel, the CI is well below 1 percent. For this study it will be assumed that the combustion inefficiency will be no greater than 0.3 percent. The emission index for both CO and HC can be determined

from Eq. (1) if a certain relationship is assumed between the inefficiency due to CO and that due to HC. As recommended by AFAPL, the following relationship is assumed,

$$EI_{co}\,QL_{co} = 2\,EI_{hc}\,QL_{hc}\,. \tag{2}$$

Substituting the appropriate values into Eq. (1), and assuming an average QL_{hc} of 10,000, we find that the EI for CO and HC are 8.3 and 1.1 g/kg, respectively.

The national standard for NO_x for power plants using liquid fuels is 0.54 g/million cal (0.3 lb/million BTU). For a combustor burning JP-4 fuel, this converts to 5.5 g of NO_x per kg of fuel burned.

Sulfur dioxide (SO_2) emission is a function of the fuel. The maximum allowable total sulfur for JP-4 is 0.4 percent by weight or 4 g/kg. The average content in a 1975 survey was 0.6 g/kg where 97.4 percent of that sampled had a sulfur content of less than 2 g/kg (Private communication, AFAPL). When the latter figure is used, the total weight of SO_2 is 4 g/kg of fuel. The national standard for SO_2 for liquid fuel power plants is 1.44 g/million cal (0.8 lb/million BTU), which is equivalent to 15 g/kg of JP-4. The 4 g/kg is then well within the national standard.

The national standard for steam power plants for particulate matter is 0.18 g/million cal (0.1 lb/million BTU). For a system using JP-4 fuel this is equivalent to 1.9 g/kg fuel.

A summary of the emission levels used in this study for a WFDS using JP-4 fuel is given in Table 2. In all cases, the emission levels are less than or equal to the national standards.

Table 2. Emission Levels of a WFDS

	g/kg of fuel
Carbon monoxide	8.3
Hydrocarbons	1.1
Nitrogen oxides (as NO_2)	5.5
Sulfur dioxide	4.0
Particulate matter	1.8

3.2 Air Quality

The Federal Environmental Protection Agency, acting under the mandate of the Clean Air Act, as amended in 1970, promulgated national ambient air quality standards on 30 April 1971 for six major air pollutants. The standards shown in Table 3

are of two kinds: primary standards to safeguard public health, and secondary standards to protect public welfare. The primary standards were to be enforced by the summer of 1975, the secondary standards must be attained within a "reasonable time" thereafter. Individual local or regional administrative jurisdictions may adopt control regulations for designated air pollutants more restrictive than proposed in Table 3. Others have proposed community air quality or source emission regulations for materials not yet covered by Federal regulations.

The air pollution levels created by the Warm Fog Dispersal System shall be compared with the secondary standards shown in Table 3 for the shortest time interval. The shortest time interval is used since the fog dispersal system will most likely operate for short periods of time ranging from 5 min to 1 hour.

Table 3. Ambient Air Quality Standards[2]

	Primary	Secondary
Particulates ($\mu g/m^3$)		
Annual Geometric Mean	75	60
Max. 24-hr Concentration*	260	150
Sulfur Oxides ($\mu g/m^3$)		
Annual Arith. Average	80 (0.03 ppm)	60 (.02 ppm)
Max. 24-hr Concentration*	365 (0.14 ppm)	260 (.10 ppm)
Max. 3-hr Concentrations*		1,300 (.50 ppm)
Carbon Monoxide (mg/m^3)		
Max. 8-hr Concentration*	10 (9 ppm)	10
Max. 1-hr Concentration*	40 (35 ppm)	40
Photochemical Oxidants ($\mu g/m^3$)		
One-hr Maximum*	160 (0.08 ppm)	160
Hydrocarbons ($\mu g/m^3$)		
Max. 3-hr Concentration*		
6 to 9 am	160 (0.24 ppm)	160
Nitrogen Oxides ($\mu g/m^3$)		
Annual Arith. Average	100 (0.05 ppm)	100

*Not to be exceeded more than once a year.

Having defined the emission limitations and the acceptable air quality levels, calculations can now be made to determine the impact of a WFDS on the air quality.

2. National Primary and Secondary Ambient Air Quality Standards (1971) Federal Register 36, No. 84, Washington, D.C.

One method of determining the air quality in the target area is to assume that the heat and pollutants are distributed in the same manner. To evaporate the fog, an average 2.5°C temperature rise or 750 calories of heat per cubic meter is required. One gram of JP-4 produces 10,380 cal of heat. Therefore, it takes 0.073 g of JP-4 to raise the temperature in one cubic meter of air by 2.5°C. Using the emission levels given in Table 2, the average concentration of pollutants over the runway and approach where the air temperature has been raised 2.5°C will be as shown in Table 4. The national standards for short term concentrations are also given. It can be seen that, except for NO_x, the concentrations over the runway are well below the maximum allowable. The NO_x is four times the annual mean, but since the system will operate, at the most, 1 percent of the time, the annual mean NO_x concentration produced by the WFDS will be well below the allowable average.

Table 4. The Average Pollution Concentrations Over the Runway and Approach as Compared with National Standards

	Target area Concentration (mg/m^3)	Standards (mg/m^3)	Time Period
CO	.61	40.	1 hr
HC	.08	.16	3 hr
NO_x	.40	.10	Annual Mean
SO_2	.29	1.3	3 hr
Particulates	.13	.15	24 hr

The target area concentrations in Table 4 represent average values. Since the heat, and therefore the pollutants, cannot be distributed uniformly throughout the clearing volume, there will be areas with higher concentrations. In general, these pockets of high concentration should not exceed two times the average concentration, except near and directly in front of the combustor outlet. Even at twice the concentration, the pollution levels are not excessive. The standards for NO_x and particulates are exceeded, but these standards are annual and 24-hr means, respectively. The WFDS will rarely operate more than two or three hrs in any one 24-hr period or more than 1 percent of the time in any one year.

The nearest populated areas tend to be at right angles to the runway. At civilian airfields this area would normally include the civilian terminal complex and the maintenance areas. At military bases, the entire military complex may be within 2 or 3 km of the runway. This complex includes such sensitive areas as living

quarters and hospitals. Turner[3] showed that the ground concentration, χ, of pollutants downstream from a continuously emitting, infinite line source can be estimated from the following equation,

$$\chi = \frac{2q}{\sqrt{2\pi}\,\sigma_z U} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] , \tag{3}$$

where q is the source strength per unit distance (g/sec/m), σ_z is the vertical dispersion parameter, which is a function of stability. U is the wind speed normal to the line source (m/sec), and H is the height of the plume centerline when it becomes essentially level.

Fog dispersal experiments at Vandenberg AFB (Kunkel et al)[4] showed that in crosswinds greater than 2 m/sec, the plume centerline remained at ground level (that is, H=0). In winds less than 2 m/sec, the buoyant plume lifted off the ground (that is, H>0), thus reducing the ground level concentrations. Maximum ground level concentrations can thus be expected to occur in winds of approximately 2 m/sec.

Assuming a near neutral, or a Pasquill Type D stability condition, the pollution concentrations downstream of the line source can be determined for the 2 m/sec wind case. Briggs[5] showed that the vertical dispersion parameter, σ_z, under Type D stability conditions can be given by Eq. (4).

$$\sigma_z = 0.06x\,(1 + 0.0015x)^{-1/2} , \tag{4}$$

where x is the distance in meters from the line source. To apply this dispersion parameters to the WFDS, the formula for σ_z must be modified since the heat and pollutants will be mechanically mixed to the appropriate clearing height, that is 15 m over the runway and up to 75 m in the approach zone. Eq. (4) should be modified to the following

$$\sigma_z = CH + 0.06x\,(1 + 0.0015x)^{-1/2} , \tag{5}$$

where CH is the clearing height in meters. The parameter x now becomes the distance from the runway or approach zone centerline.

3. Turner, D. B. (1969) Workbook of Atmospheric Dispersion Estimates, USDHEW, PHS Pub. No. 999-AP-26.
4. Kunkel, B.A., Silverman, B.A., and Weinstein, A.I. (1973) Thermal and Chemical Fog Dissipation - Results of Field Experiments at Vandenberg AFB, California During July 1972, AFCRL-TR-73-0502.
5. Briggs, G.A. (1973) Diffusion Estimations for Small Emissions, Environment Res. Lab., Air Resources Atmos. Turb. and Diffusion Lab., 1973 Annual Rep., ATDL-106, USDOC-NOAA.

Using Eqs. (3) and (5), the pollution concentrations as a function of distance from the runway and approach zone centerlines can be determined. Table 5 shows the concentration at various distances downwind of the approach zone and rollout portion of the runway. The heat outputs from Table 1 and emission levels from Table 2 were used in the calculation. An average clearing depth of 60 m was assumed in the approach zone. The concentration of pollutants from the touchdown zone is similar to that from the rollout portion of the runway, and therefore are not shown in Table 5. The EPA short term, secondary standards (see Table 3) are also shown for comparison. The only pollutant that exceeds the EPA standards is NO_x. However, since the NO_x standard is for an annual mean concentration and since a fog dispersal system will most likely operate less than one percent of the time, the NO_x concentrations produced will not be harmful to human or animal life or vegetation or interfere with comfort.

Table 5. Pollution Concentrations (mg/m^3) in a 2 m/sec Wind at Various Distances from the Runway and Approach Zone Centerline

ROLLOUT ZONE								
	mg/g fuel	Downwind Distance (m)						EPA Std.
		200	500	1000	1500	2000	2500	
CO	8.3	.39	.27	.19	.15	.13	.12	40.
HC	1.1	.05	.03	.02	.02	.02	.01	.16
NO_x	5.5	.25	.17	.12	.10	.09	.08	.10
SO_2	4.0	.19	.13	.09	.07	.06	.06	1.3
PM	1.8	.08	.05	.04	.03	.03	.02	.15
APPROACH ZONE								
	mg/g fuel	Downward Distance (m)						EPA Std.
		200	500	1000	1500	2000	2500	
CO	8.3	.64	.55	.46	.41	.38	.35	40.
HC	1.1	.09	.08	.07	.06	.05	.05	.16
NO_x	5.5	.42	.36	.31	.27	.25	.23	.10
SO_2	4.0	.31	.26	.22	.20	.18	.17	1.3
PM	1.8	.14	.12	.10	.09	.08	.07	.15

Pollution concentrations downstream will vary with different wind and stability conditions. The concentrations will increase with more stable conditions and lighter winds. However, in winds less than 2 m/sec, the ground concentration will actually decrease since the main part of the plume will be above ground.

Calder[6] derived an approximate line-source formula for determining concentrations when the wind is not perpendicular to the line source. He shows that as the wind varies from perpendicular to within 15° of parallel to the line source, the pollution concentrations at a given distance normal to the line source increase by roughly 50 percent. Even with this much of an increase, the concentrations from a WFDS will generally be well within the EPA standards.

3.3 Noise Impact

The noise created by the fog dispersal system is a major environmental concern. Fog dispersal systems will operate most frequently at night and early morning, and therefore particular attention must be given to the noise problem, especially for those systems installed near residential areas.

Sound intensity is subjectively measured by the human ear. Although the ear responds in a nonlinear fashion, experiments have demonstrated that the ear responds logarithmically in relation to the loudness of the applied stimuli. Noise is commonly measured in terms of decibels (dB)—a dimensionless unit used to express the logarithm of the measured quantity to a reference quantity.

There are many different types of sound levels. The two more common ones are the A-weighted (dBA) and the C-weighted (dBC) sound levels. The "A" weighted overall sound level is a single number representing the summation of all frequency components contributing to the overall level, but with the heaviest weight placed on the higher frequencies. The "C" weighted overall sound level is one in which each frequency contributing to the overall level is recorded with little weighting change of its actual level. The ear's performance may be permanently degraded by exposure to certain sound levels for time durations in excess of certain limiting values. The damaging effect of a noise field also depends on the frequency components present in it. The high frequency sounds are more damaging to the ear and therefore the "A" weighted sound level, which places more weight on the higher frequencies, is a more meaningful sound level than the "C" weighted sound level.

Acceptable noise levels for various land uses have been established by various government agencies. Table 6 shows the acceptable noise levels for various land uses as established by the U.S. Department of Transportation.

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6. Calder, K. L. (1973) On estimating air pollution concentrations from a highway in an oblique wind, Atmospheric Environment, pp 863-868.

Table 6. Design Noise Levels and Land Use Relationships

Land Use Category	Design Noise Level	Description of Land Use Category
A	60 dBA (Exterior)	Tracts of land in which serenity and quiet are of extraordinary significance and serve an important public need.
B	70 dBA (Exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, parks, picnic and recreation areas.
C	75 dBA (Exterior)	Developed lands, properties or activities not included in categories A and B, above.
D	-----	Undeveloped lands - future use to be compatible with anticipated noise levels.
E	55 dBA (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums. (For use when no exterior noise-sensitive land use is identified.)

SOURCE: Policy and Procedures Memorandum 90-2, U.S. Department of Transportation, Federal Highway Administration - February 1973.

Knowing the type of land usage within 1 or 2 km of the runway, acceptable noise levels for the combustors can be established. The noise level at any distance from an array of combustors can be determined by accumulating the noise intensities from all of the combustors along the two rows and then converting the intensity to a dB value. The noise intensity, I, drops off as the square of the distance, R, such that

$$I_1 = I_o R_o^2 / R_1^2 . \tag{6}$$

The noise intensity from n sources of the same noise level can be determined by the following equation

$$I_1 = I_o R_o^2 / \sum_1^n R_1^2 . \tag{7}$$

The dBA level at a given point is then equal to

$$dBA = 10 \log_{10} I_1 . \tag{8}$$

Figure 3 shows the drop-off in the noise level with distance from the nearest combustor, the nearest combustor being the middle combustor of the closer line. Each individual combustor is assumed to have a noise level of 85 dBA at 15 m from the combustor. The change in the dBA level with distance is independent of the noise level of the source, and therefore the curves in Figure 3 can be simply displaced up or down for different combustor noise levels. Curves B and C represent two 1500 m lines of approach zone and rollout zone combustors, respectively, as specified in Table 1. Curve C represents two 3000 m lines of rollout zone combustors. Curve A represents the drop-off in the dBA level for a single combustor. The effect that the second row (furthest row) has on the overall dBA level is to add only 2 or 3 dB to the overall noise level. Adding to the length of the combustor lines has little effect on the noise level near the combustors but has greater effect at greater distances from the combustors.

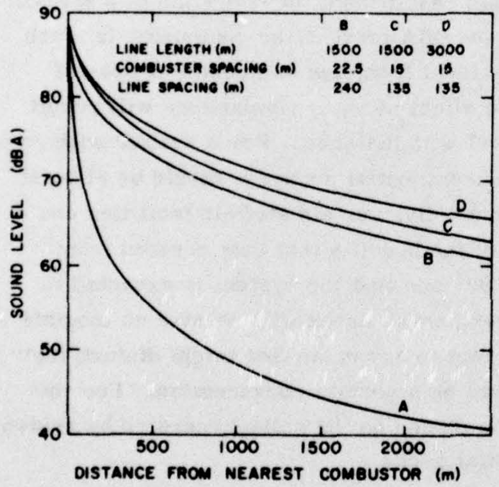

Figure 3. Noise Levels as a Function of Distance from a Single Combustor (A) and from the Nearest Line of a Two-Line WFDS (B, C, D)

A comparison can be made between the curves in Figure 3 and the noise level/land use relationships shown in Table 6. The noise levels resulting from the WFDS will not be a nuisance within commercial areas that are greater than 300 to 700 m away (75 dBA). Residential areas should be at least 800 to 1500 m away (70 dBA).

A change of 1 dB in the combustor noise level will result in a 100 to 150 m change in these critical distances.

The dBA/distance relationships shown in Table 6 assume no obstructions or wind. Trees, buildings and hills will all help to reduce the noise level at a given distance from the combustors. The noise levels will be greater downwind of the WFDS and less upwind of the system.

4. CONCLUSIONS

The effect of a Warm Fog Dispersal System (WFDS) on the environment depends on many factors. These factors include the emission and noise levels of the combustors, the number of combustors, the amount of fuel consumed, and the wind and stability conditions.

Using heat outputs established under previous work and emission and noise levels that are within the state-of-the-art, the effect that the WFDS has on the surrounding environment has been evaluated. Calculations show that even within the cleared area, the pollution concentrations, on the average, are within the EPA standards. Concentrations will decrease with distance from the WFDS, and therefore no unpleasant or harmful effects should result from the operation of a WFDS.

Noise could be a nuisance problem if the dBA level of the combustor is much above 85 dBA at 15 m. Although the noise level from one combustor drops-off quite rapidly with distance, the cumulative effect of many combustors will result in a much slower drop-off in the sound level with distance. For a system with combustors that emit 85 dBA, commercial and residential property should be at least 500 and 1200 m away, respectively. Undoubtedly, certain airfield facilities could tolerate being closer than 500 m because of the benefits that they derived from operation of the WFDS and the short time periods that the system is expected to operate. The people in the surrounding residential areas will receive no tangible benefit from the system and will be intolerant to any noise that might disturb their sleep or interfere with their ability to carry on a normal conversation. For this reason, particular attention will have to be placed on the noise generated by systems installed at airfields located near residential areas.

References

1. Kunkel, B. A. (1975) Heat and Thrust Requirements of a Thermal Fog Dispersal System, AFCRL-TR-75-0472.

2. National Primary and Secondary Ambient Air Quality Standards (1971) Federal Register 36, No. 84, Washington, D.C.

3. Turner, D. B. (1969) Workbook of Atmospheric Dispersion Estimates, USDHEW, PHS Pub. No. 999-AP-26.

4. Kunkel, B. A., Silverman, B. A., and Weinstein, A. I. (1973) Thermal and Chemical Fog Dissipation - Results of Field Experiments at Vandenberg AFB, California During July 1972, AFCRL-TR-73-0502.

5. Briggs, G. A. (1973) Diffusion Estimation for Small Emissions, Environment Res. Lab., Air Resources Atmos. Turb. and Diffusion Lab., 1973 Annual Rep., ATDL-106, USDOC-NOAA.

6. Calder, K. L. (1973) On estimating air pollution concentrations from a highway in an oblique wind, Atmospheric Environment, pp 863-868.